CONTINUOUSLY ADJUSTED-BANDWIDTH DISCRETE-TIME PHASE-LOCKED LOOP

This is a continuation-in-part of U.S. Provisional Application Ser. No. 60/037,914, filed Mar. 12, 1997.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention is generally directed to wireless digital communication systems. More particularly, the invention is directed to a code division multiple access (CDMA) receiver having a continuously adjustable bandwidth phase-locked loop for accurately determining the carrier frequency of a received signal.

2. Description of Related Art

Over the last decade consumers have become accustomed to the convenience of wireless communication systems. This has resulted in a tremendous increase in the demand for wireless telephones, wireless data transmission and wireless access to the World Wide Web. Since the amount of available RF spectrum is fixed, the need to utilize the RF spectrum more efficiently has become paramount.

CDMA communication systems have shown promise in the effort to provide more efficient utilization of the RF spectrum, particularly Broadband Code Division Multiple Access™ or (B-CDMA™) communication systems. B-CDMA™ communication systems permit many communications to be transmitted over the same bandwidth, thereby greatly increasing the capacity of the RF spectrum. In a B-CDMA™ communication system, an information signal at the transmitter is mixed with a pseudorandom "spreading code" which spreads the information signal across the entire communicating bandwidth. The spread signal is upconverted to an RF signal for transmission. A receiver, having the same pseudorandom spreading code, receives the transmitted RF signal and mixes the received signal with an RF sinusoidal signal generated at the receiver by a first-stage local oscillator (LO) to downconvert the spread spectrum signal. The spreaded information signal is subsequently mixed with the pseudorandom spreading code, which has also been locally generated, to obtain the original information signal.

In order to detect the information embedded in a received signal, a receiver must know the exact pseudorandom spreading code that was used to spread the signal. All signals which are not encoded with the pseudorandum code of the receiver appear as background noise to the receiver. Accordingly, as the number of users that are communicating within the operating range of a particular base station increases, the amount of background noise also increases, making it difficult for receivers to properly detect and receive signals. The transmitter may increase the power of the transmitted signal, but this will increase the noise as seen by other receivers. Therefore, increasing the signal-to-noise ratio of a received signal without requiring a corresponding increase in the transmission power of the signal is desirable.

One way to increase the signal-to-noise ratio of a received signal is to ensure that the first stage local oscillator (LO) at the receiver is at the same frequency as the received RF carrier signal. If there is a slight frequency offset, the offset will manifest itself in the baseband section of the receiver as a phase error on the decoded QPSK symbol, resulting in a degradation of the quality of the communication.

Accordingly, it is critical to properly detect the frequency of the received RF carrier signal in order to optimize the quality of the received signal.

SUMMARY OF THE INVENTION

The continuously adjusted-bandwidth phase-locked loop (PLL) of the present invention is used by a B-CDMA™ receiver to correct for any deviation, or offset, that may exist between the received radio frequency (RF) carrier signal and the frequency of the first stage LO that converts the received RF carrier signal to an intermediate frequency (IF). The PLL in the receiver includes a filter with an adjustable bandwidth. A wider bandwidth is used during initial acquisition of the received signal. After the PLL has acquired the received carrier signal using the wider bandwidth, the bandwidth of the filter is gradually narrowed to provide a low steady-state error. Accordingly, it is an object of the invention to provide an improved CDMA receiver which corrects for any offset that may exist between the received RF carrier signal and the frequency of the first stage LO.

Other objects and advantages will become apparent to those skilled in the art after reading the detailed description of a presently preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a communication network embodying the present invention;

FIG. **2** shows propagation of signals between a base station and a plurality of subscriber units;

FIG. **3** is a block diagram of the PLL implemented in a programmable digital signal processor within the receiver section;

FIG. **4** is a detailed block diagram of a rake receiver used in accordance with the teachings of the present inventor;

FIG. **5** is a block diagram of the continuously adjustable bandwidth PLL in accordance with the present invention;

FIG. **6** is a diagram of the mapping of polar and Cartesian coordinates;

FIG. **7** is a look-up table utilized to implement the arctangent analyzer;

FIG. **8** is the preferred embodiment of a look-up table utilized to implement the arctangent analyzer;

FIG. **9** is a block diagram of the PLL filter comprising a lag filter and a lead filter in accordance with the present invention;

FIG. **10** is a block diagram of the bandwidth control section;

FIG. **11** illustrates the transfer function utilized in the bandwidth calculation unit;

FIG. **12**A is a signal diagram of the carrier offset frequency estimate provided by the output of the lag filter;

FIG. **12**B is a signal diagram of the phase correction in degrees provided by the output of the lead filter;

FIG. **12**C is a signal diagram of the bandwidth control signal versus time;

FIG. **12**D is a signal diagram of the dynamic bandwidth versus time; and

FIG. **13** is a flow diagram of the method of adjusting the PLL bandwidth in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment will be described with reference to the drawing figures wherein like numerals represent like elements throughout.

A communication network **2** embodying the present invention is shown in FIG. **1**. The communication network